RECEIVED
CENTRAL FAX CENTER

MAY 29 2007

REMARKS

Claims 1 – 31 are presently pending. In the above-identified Office Action, the Examiner rejected Claims 1 – 3, 7, 8, 12, 13, 26 and 27 under 35 U.S.C. 103(a) as being unpatentable over Hemmati ('480). Claims 4 – 6, 9 – 11, 14 – 22, 24, 25, and 28 – 31 were rejected under 35 U.S.C. 103(a) as being unpatentable over Hemmati ('480) in view of Halmos *et al.* (2002/0051470). Claim 23 was allowed.

The indication of allowable subject matter is gratefully acknowledged. For the reasons set forth more fully below, the subject application is deemed to properly present claims patentable over the prior art. Reconsideration, allowance and passage to issue are respectfully requested.

As noted previously, the present invention addresses the need in the art for a short pulse length, high-energy eye-safe laser. The art is addressed by the laser of the present invention, which includes an active medium disposed within a resonator; a material operationally coupled to the medium and having a transmittance property that varies in response to incident energy; and an arrangement disposed external to the medium for applying energy to the material with a pulse that is shorter than a round trip delay time of light within said resonator.

The invention is set forth in Claims of varying scope of which Claim 1 is illustrative. Claim 1 recites:

> 1. A laser comprising:
> an active medium disposed within a resonator;
> a material operationally coupled to said medium and having a transmittance property that varies in response to incident energy; and
> means disposed external to said medium for applying energy to said material, **said means having a response time that is shorter than a round trip delay time of light within said resonator.** (Emphasis added.)

None of the references, taken alone or in combination, teach, disclose or suggest the invention as presently claimed. That is, none of the references teach, disclose or suggest a laser with an active medium disposed in a resonator, a material having a

transmittance property that varies in response to incident energy and means for applying energy to the material with a response time that is shorter than a round trip delay time of light within the resonator.

In the Office Action, the Examiner relied once again on Hemmati ('480). Hemmati purports to teach a laser with an optically driven Q-switch. The Examiner suggests that Hemmati teaches the invention as claimed. However, there is no teaching in the reference of a laser with an active medium disposed in a resonator, a material having a transmittance property that varies in response to incident energy and means for applying energy to the material with a response time that is **shorter than** a round trip delay time of light within the resonator.

In response to Applicants argument above, the Examiner acknowledged that Hemmati did not disclose means for applying energy to the material with a response time that is shorter than or equal to a round trip delay time of light within the resonator. The Examiner suggested, however, that Hemmati shows a low current control source controlling a laser diode output that switches or triggers a Q switch at a desired wavelength and that such disclosure is a disclosure of a general condition of a claim such that the invention as claimed involves only an optimal or workable range within the level of skill of one of ordinary skill in the art. However, this assertion is in error and reflects a misunderstanding of the invention.

Indeed, the Examiner's own attempt to apply the teaching to the invention as claimed underscores the shortcoming of the Examiner's assertion. That is, the Examiner suggests that with Hemmati's teaching, a control source can vary from a higher frequency to a lower frequency such that when a laser oscillating longitudinally, is equally to an integral multiple of the transverse oscillation, then the wavelengths will phase lock. As stated previously, there are at least two problems with this assertion.

First, the Examiner's position is not supported by the reference. The reference appears to be incapable of enabling mode-locking inasmuch as a high average transparency condition can not be implemented in the disclosed dye with the disclosed scheme for pumping into an excited state where it strongly absorbs at the laser wavelength. In order to implement a mode-locked SA technique one needs to reduce the hold-off substantially to facilitate a quasi-continuous wave operation with only a slight modulation at the roundtrip frequency.

Secondly, and more importantly, the Examiner's position misses the point. The claimed application of energy to the material with a response time that is shorter than or equal to a round trip delay time of light within the resonator is for the purpose of achieving a fast bleaching of a saturable absorber material for passive Q-switching, not simply or necessarily for mode-locking as suggested by the Examiner. As discussed in the Background of the Application:

> There is an increasing need for compact active laser imaging sensors for detection and identification in battlefield environments and other applications. For these applications, a pulsed transmitter is used for flash ladar implementation as these devices offer high resolution for hidden and/or camouflaged target detection and identification. These applications require a laser source that is eye-safe (i.e. with a wavelength of 1400 – 1700 nm), with a short pulse width (i.e., less that .5 nanoseconds in duration) and high energy per pulse (i.e., 1 – 5 milli-joules). Short pulse width lasers are needed to provide sufficient resolution to permit automatic target resolution. High energy per pulse is required to allow for standoff operation.
>
> A laser is a device that emits a spatially coherent beam of light at a specific wavelength. In a laser, a lasing element is placed within a laser resonator cavity and pumped with an energy source such as a flash lamp. The pumping action produces stored energy and gain within the lasing element. When the gain exceeds the losses, so that there is a net light amplification per round trip of the light in the resonator cavity, laser light begins to build up in the cavity, and stored energy is extracted from the lasing element.
>
> This energy can be released in the form of a very short, intense light pulse by using a device called a Q-switch. A laser can also operate in a mode-locked mode. A laser resonator of length L supports a number of modes separated by the inverse-round-trip time of the light field given by:
>
> $$\Delta\nu = \frac{c}{2L} \qquad [1]$$
>
> where c is the speed of the light field in the laser cavity. The number of longitudinal modes that a laser can support is governed by the gain bandwidth of the laser gain medium, $\Delta\vartheta$. This gain bandwidth in common laser systems such as Nd:YAG is typically on the order of 100 GHz. Hence, cavity / resonator lengths of ~ 1 meter can support ~ 103 modes. (Conversely, ultra-short resonators such as microchip lasers having resonator lengths of ~ 1 mm will typically operate in a single longitudinal mode regime).
>
> In order to generate short pulses (on the order of a nanosecond or less), the laser will typically have a Q switch. A Q-switch can be an active device that is controlled or driven by an external signal. The Q-switch can also be a passive structure that has no external control, but instead operates periodically as a result of its own properties. Passive Q-switches, when available, are usually the preferred method for obtaining Q-switched pulses because of

their low cost, efficiency, reliability, simplicity, and other advantages.

A saturable absorber (SA) – or bleachable filter – can be used as a passive Q-switch. A saturable absorber is a material: solid (crystal, glass, polymer); or liquid (dye) having transmittance properties that vary as a function of the intensity of the incident light that falls upon this material. When light of low intensity is incident upon the saturable absorber, its light transmittance is relatively low, resulting in high cavity losses. As the incident light energy increases, due to the buildup of energy within the laser resonator cavity, the light transmittance of the SA material increases. At some point, the light transmittance increases to a level such that the SA "bleaches", i.e., becomes transparent, so that the cavity losses become low, and an intense Q-switched light pulse is emitted.

To achieve short pulse widths, the SA must switch quickly to the transparent state. However, for fast operation, the absorption cross-section of the SA is required to be much much larger than the stimulated emission cross-section of the laser gain medium: $\sigma_{SA} >> \sigma_{se}$. If this is not the case, Q-switch performance generally degrades and output pulse widths increase. Utilization of external pumping of the SA can overcome the limitation indicated by $\sigma_{SA} >> \sigma_{se}$. Thus, many more SA materials can be effectively utilized and could enable SA switches to be developed at wavelengths where, at present, none exist.

Unfortunately, the cross-section of conventional saturable absorbers is typically on the order of 10 times or less the cross-section of conventional laser gain mediums. Hence, shorter pulse widths have not heretofore been possible.

To compensate for this shortcoming, prior approaches have involved the use of high gain Neodymium microchip lasers. In this application, the output is typically converted to an eye safe range using an optical parametric amplifier. Unfortunately, Neodymium is a poor energy storage laser material and outputs pulses only on the order of micro-joules in energy.

Another approach involves the use of erbium-ytterbium glass lasers with short end pumped cavities to achieve the desired short pulse widths. However, erbium-ytterbium glass microchip lasers are characteristically low gain devices. In addition, the erbium-ytterbium transfer process required by these devices typically necessitates the use of an energy inefficient pumping scheme. Consequently, erbium-ytterbium lasers are also typically too limited with respect to energy output levels to be used for the more demanding current applications mentioned above.

Hence, a need remains in the art for a short pulse length, high energy eye-safe laser.

The present invention addresses this need with a solution that is clearly more than the result of a discovery of an optimal range of operation as suggested by the Examiner. Hence, Applicants submitted that inasmuch as Hemmati was relied on as the primary reference in the rejection of the claims, Claims 1 – 13 and 15 – 31 should be allowed.

However, in the most recent Office Action, without comment as to Applicants previous Remarks, the Examiner reasserts that: ". . . *it is inherently obvious and within one skill in the art to recognize, the energy from the external means response time is shorter then its round trip delay within the resonator because of additional time spent within the resonator.*"

In response, Applicants encourage the Examiner to consider that from a Q-switching perspective, normally, the resonators are long such that the build up time is on the order of ~10X pulse width and if a typical resonator has a 20 ns pulse width, the switching time of the external source can be as long as ~200 ns (well within most diode drivers/high power LED systems). If, however, one is designing for a 1 ns pulse resonator and the ring down time of the pulse in the resonator is short (due to extremely low output coupler reflectivity), then the system for dispensing the energy of the external light trigger needs to be uniquely designed – as would be the ultra-short pulse resonator. This is not inherently obvious to those skilled in the art as it is a specific implementation of a high speed switched SA- based Q-switched laser.

The Examiner further asserts that: ". . . *where the general conditions of a claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art, in this case the control source can vary from higher to lower frequency such that when a laser oscillating longitudinal is equal to an integral multiple of the transverse oscillation, then the wavelengths will phase lock.*"

In response, Applicants note that firstly, the Examiner must have meant multiples of longitudinal oscillations as the transverse modes are referred to spatial modes. Secondly, the multiples of round trip time/mode separations only holds true when that number is not an excessively high integer multiple of the round trip mode separation time since mode jitter will prevent an effective passive/satuarble absorber (SA) mode locking to take effect. Again, for extremely short resonators, the bandwidth associated with the mode separation can be as high as tens of GHz. Even if one takes 10X or even 100X relaxation on this bandwidth – it still calls for a high bandwidth specific designed telecom – type light source in order to effect efficient mode locking. Therefore, Applicants again reject the argument that the invention as claimed is obvious in view of the prior art.

Regarding Claim 14, inasmuch as and contrary to the assertion of the Examiner, Halmos does not teach, disclose or suggest a quasi-monolithic laser assembly ring as claimed, Claim 14 should be allowable as well. That is, the elements 120, 140 and 150 cited by the Examiner are merely a mirror, a polarizer and a Q-switch respectively. As stated previously, no mention is made of a diode laser assembly ring.

Accordingly, Applicants respectfully submit that Claims 1 – 22 and 24 – 31 are allowable. Reconsideration, allowance and passage to issue are respectfully requested. **In the event that the Examiner maintains any of the rejections, Applicants respectfully request the Examiner to consider the arguments submitted above and respond to the arguments point-by-point to set up the issues for appeal.**

Respectfully submitted,
Kalin Spariosu *et al.*

By Leonard A. Alkov
Leonard A. Alkov, Esq.
Attorney for Applicants
Registration No. 30,021

Raytheon Company
Intellectual Property & Licensing
EO/E04/N119
P.O. Box 902
El Segundo, CA 90245-0902

(310) 647-2577 (telephone)
(310) 647-2616 (facsimile)